REMARKS

Claims 1 - 17 are in this application and are presented for reconsideration. Claim 1 has been amended to improve the clarity and the style of this claim.

By this Amendment, Applicant as amended and added several claims to overcome the Examiner's rejections and respectfully makes assertions for overcoming the rejections of the outstanding Office Action dated June 21, 2004 in the following paragraphs.

Applicant has added new claims 15 - 17 which are supported by the specification (see in particular, page 9) and also on Figs. 1 and 2. The new claims 15 - 17 include subject matter which defines over the prior art as shall be discussed below.

THE CLAIM REJECTIONS - 35 USC § 102:

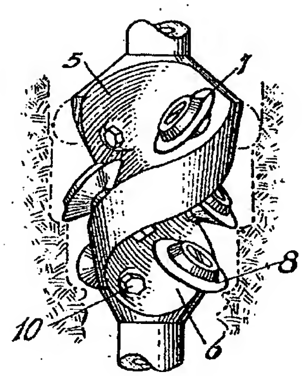
Claims 8 - 12 and 14 have been rejected under 35 USC § 102(b) as being anticipated by Akeyson (U.S. Patent 2,184,108, "Akeyson '108", hereinafter).

The invention provides surface miner with mini-disk bits. The mini-disk bits form a virtual cutting roller body or what could be considered a circumferential interface that has cylindrical middle area and a frusta shaped area at each side. This virtual cutting roller body is symmetrical.

The mini-disk bits in the cylindrical area include one half of the disks directed in one direction and the other half of the disks in the other direction.

The mini-disks in the frusta area are directed inwardly and mini-disks at the edge have special characteristics . Akeyson '108 fails to teach each of these features.

Akeyson '108 discloses a reamer for the purpose of enlarging or cutting bore holes (see Fig. 7).

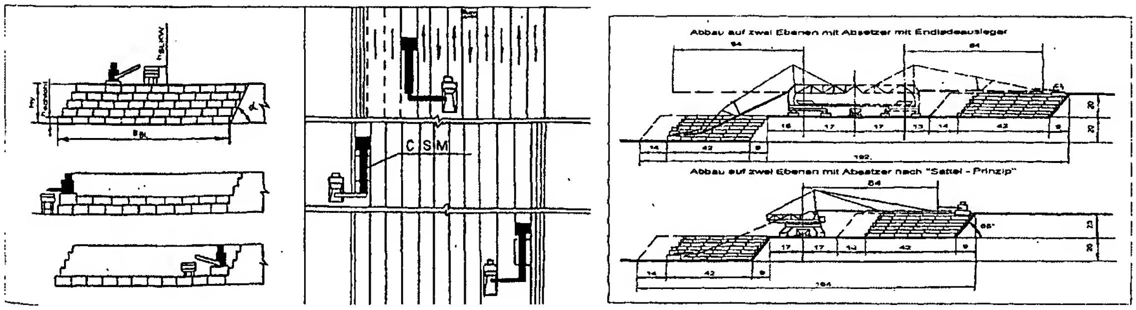


As can be seen in Figure 7 of Akeyson '108, the prior art reference discloses a drilling device or a mining device for underground drilling which is to be done axially along the axis illustrated by the cylindrical portion on the top and on the bottom of the device.

The prior art as a whole including the Akeyson '108 neither teaches nor suggests the present invention as claimed. As indicated by the title, specification and the claims, the present invention is a cutting roller for surface mining involving block mining.

This is a mining of a surface in parallel to the direction of travel and perpendicular to the axis of rotation.

The block mining is substantially different from an underground mining. In block mining, the blocks of material are removed (see illustration) layer-by-layer from the top layer down (see Fig. 3 and Fig. 4 of the technical article "Constructional and Technical Operational Preconditions and Practical Results..." as provided in the Information Disclosure Statement).



The problems posed by the surface mining is uniquely different from problems encountered in underground mining, boring or tunneling. Specifically, as noted in the application, the free-cutting by mini-disk bits requires a considerably higher energy consumption and wear and calls for special equipment for mining members with tools in the edge area in comparison to the larger middle portion. In addition, pulverized rocks or minerals generate increased dust emission during the mining operation. Thus, lateral accumulations pose serious problem to strip mining process.

The current invention as claimed provides a vastly improved and inventive method of strip mining which solves the problem of lateral accumulations and dust. Specifically, the present invention as claimed equips a cutting roller with mini disk bits for surface mining purposes. Such cutting roller, according to the present invention as claimed, advances in parallel (radially) to the center line, in explicitly also the axis of the rotation of the roller. In contrast, Akeyson '108 discloses an apparatus for advancing axially from top to bottom.

This directional difference between the prior art and the present invention as claimed has an important consequence on the operation of the cutting mini-disk bits. An apparatus

according to the prior art embodies fewer disk bits pressing on the mineral ores that needs to be mined. In contrast, the present invention as claimed teaches a numerous number of mini-disk bits, quite a number of which are pressing on the mineral ores to be mined at certain instance of time period.

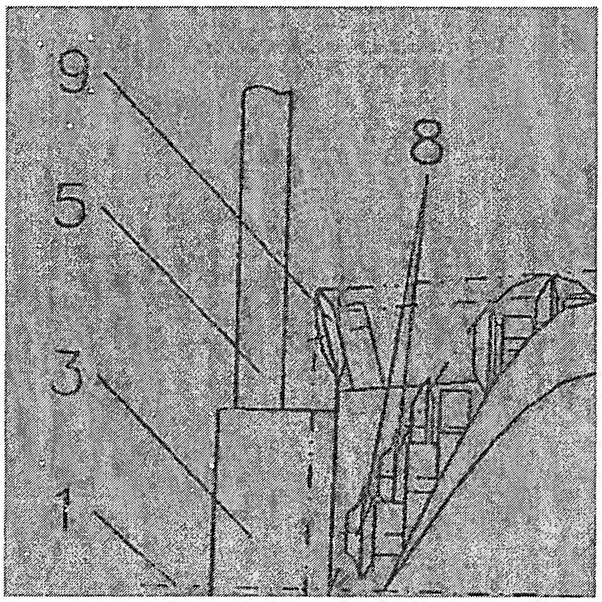
In other words, in drilling devices or mining devices in underground mining, only a few disk bits are arranged on a cutting roller or a drilling head. This means that only a few disk bits are engaged at any time. As a result, the pressure originating from the machine is transmitted to this small number of disk bits only. The pressure per disk bit that is applied to the material to be mined is consequentially high. As a result, high mining output must be reached per disk bit.

In contrast, in a surface mining device with a roller arranged in front, where the surface miner is equipped with disk bits in the same manner, high forces must be applied during the mining operation because a larger number of disk bits are arranged on the circumference of the roller. These larger number of disk bits will always engage the material to be mined at the same time.

However, the consequence of the use of mini disk bits in a surface mining is that because of the smaller circumference of the bits, only a smaller section of the cutting edges is pressed against the material to be mined at any time. Thus, a larger number of bits can act on the ground and thus perform mining at equal feed force of the surface miner. Since the same effect is not achieved over the entire width of the roller during the breaking off of the material by the disk bits, but more unfavorable conditions prevail on the outside, the disk bits must be

arranged in a more closely packed arrangement on the circumference of the roller.

A more closely packed arrangement is also true of the lateral distance between the disk bits next to one another. The distance between the cutting circles formed by the tip of the circulating disk bits is therefore selected to be smaller towards the outside.



Another important feature of the present invention, as can be seen from Fig. 1, is that the characteristics of the disk bits at the edge are different from the disk bits at the middle portion of the cylinder. Specifically, the disk bits number 8 include higher slope on the outer side of the disk.

Furthermore, it should be born in mind that the cutting or breaking geometry of a disk bit is selected with the aim of always splitting off the material from the solid ground in one direction. To insure this, a disk bit always has two cutting flanks arranged at different angles relative to its cross-action. According to Fig. 4 of the enclosed technical article entitled "Continuous Mining Process in Solid Rock," the solid rock is always broken off on the side of the greater slope. The disk bits are therefore arranged on the circumference of the roller on both sides such that the solid rock located entirely on the outside is broken off by the disk bits arranged there in the direction of the middle of the roller.

In all other disk bits, the outwardly directed flanks have a greater slope, as a result of which the solid rock broken off is guided away by the conveying screws 10, 11, 12, 13 arranged directly next to the disk bits and thus it cannot settle between the disk bits and their conveying screws. This avoids the problem of clogging and consequential disturbance in the flow of material.

Since the operation of the loosening of the solid rock is not so favorable in the two edge areas of the roller as in the larger middle area, the disk bits are arranged, as was described above, at more closely spaced locations from one another on the circumference of the roller.

Furthermore, these more unfavorable conditions are taken into account by selecting the cutting circle diameter of the disk bits arranged there to be smaller according to Fig. 3 of the patent drawings.

An additional important feature of the present invention includes the mini disk bit (9) used at two outer edges of the cutting roller which are directed obliquely toward the outside as free-cutting bits, thus providing additional functionality to the present invention in overcoming accumulation and other problems.

The mining technology is such that the solid rock that is left in place as an elevation as a result is located in the middle of the roller during the removal of the subjacent block being mined and the conditions of the removal are thus more favorable for the removal of the native solid rock located at the higher level.

None of the important features described above are disclosed by Akeyson '108. Applicant further notes that Akeyson '108 does not provide any suggestion or motivation

which would lead a person of ordinary skill in the art to use the disclosed apparatus for a surface mining process. Instead, Akeyson '108 leads a person of ordinary skill in the art to utilize the bits to drill underground holes which is completely different from the present invention as claimed. Thus, it is Applicant's position that Akeyson '108 does not anticipate nor suggest the present invention as claimed.

CLAIM REJECTIONS - 35 USC § 103:

Claim 13 has been rejected under 35 USC § 103 as being unpatentable over Akeyson '108 in view of the British Document, GB 2 035 417 (GB 2 035 417, "British Document", hereinafter).

The British Document discloses a cutting tool for mounting on a rotary cutting head comprising a shank for inserting in an aperture of the rotary cutting head.

It is Applicant's position that claim 13 is not obvious in view of the British Document. The present invention as claimed provides for a combination of features not taught by the prior art as a whole including the British Document. For instance, there are several differences which are not disclosed nor suggested by the prior art references such as direction of the mini-disk bits around the middle portion, near the end and at the edge of the roller body. In addition, frusta shape is not disclosed nor suggested in any of the prior art references.

Such different structural features in combination with other features for the present invention as claimed provide the advantage as mentioned for a surface mining and not for a tool for cutting heads. Therefore, Applicant finds no incentive in the British Document which

would lead a person to all the structural features of the bits and the rolling body as well as the end portion as claimed.

The above advantages are due to the combination of features as claimed. The advantages cannot be obtained from the prior art. The invention solves the problem of surface mining as mentioned previously and the prior art does not recognize these problems and directs the skilled artisan in a different direction. The British Document leads the skilled artisans in a direction for using the mini disk bits for cutting tool.

The British Document clearly fails to teach and fails to suggest the combination of the invention. Absent a teaching or a suggestion of the important feature of the invention, the combined references clearly do not direct the person of ordinary skill in the art toward the combination as claimed.

There must be some suggestion or teaching in the prior art as a whole which would lead the person of ordinary skill in the art to provide the combination as claimed. As the prior art as a whole fails to direct the person of ordinary skill in the art toward the claimed combination, the invention should be considered not anticipated, non-obvious and thus patentable.

Claims 1 - 7 have been rejected under 35 USC § 103(a) as being unpatentable over Nies et al. (U.S. Patent 6,224,163, "Nies '163", hereinafter). Nies '163 discloses a milling roller module for a surface miner including a milling roller, and a take-up chute.

Applicant has reviewed Nies '163 and finds no teaching nor a suggestion of a substantially cylindrical roller basic body including frusta edges and mini disks at outer edges which are free cutting bits.

Nies '163 reference also clearly fails to teach and fails to suggest the combination of all the features of the present invention as claimed. Absent a teaching or suggestion of the important feature of the invention, the combined references clearly do not direct the person of ordinary skill in the art toward the combination as claimed. Thus, the invention should be considered not anticipated, non-obvious and thus patentable.

As one can see, the present invention is an improvement over the prior art and we will improve the problem of the accumulation of minerals at the edges and the dust. Therefore, Applicant respectfully requests favorable consideration of the claims as presented.

Accordingly, Applicant respectfully requests that the Examiner reconsider the rejection in view of the new claim and in view of the discussion above.

As the prior art fails to suggest the combination of features as claimed, Applicant respectfully requests that the Examiner favorably consider the claims as now presented.

If the Examiner has any comments or suggestions which would further favorable prosecution of this application, the Examiner is requested to contact Applicant's representative by telephone to discuss possible changes.

The Examiner is requested to consider a reference cited by the Applicant. Applicant submits herewith the Government Fee relating to the Information Disclosure.

The article entitle Continuous Mining Process in Solid Rock discloses mining methods with a cutting tool. Consideration of this reference is respectfully requested.

At this time, Applicant respectfully requests reconsideration of this application in view of the above amendments and remarks, and Applicant respectfully solicits allowance of this application.

Respectfully submitted
for Applicant,

By: ______________________
John James McGlew
Registration No. 31,903
McGLEW AND TUTTLE, P.C.

JJM/DWK:tf/jms

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LIST OF REFERENCES CITED
BY APPLICANT
(Use several sheets if necessary)

Atty Docket No.: 71095
Ser. No.: 10/671,125
Applicant: EHLER et al.
Filing Date: September 25, 2003
Group: 3673

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

Examiner Initial	Author	Date	Title	Textbook in	Translation Yes/No
	G. GUNZE, A. EHLER, B. GOERICKE	April/June 2001	CONTINUOUS MINING PROCESS IN SOLID ROCK	Surface Mining Braunkohle & Other Minerals	YES

Examiner

Date Considered

Continuous Mining Process in Solid Rock

Kontinuierlicher Gewinnungsvorgang im Festgestein

G. Kunze and A. Ehler, Germany
B. Goericke, Russia

1. Introduction

Mining methods with the cutting tool in direct contact with the rock have certain energetic, ecological and economic advantages [3]. Nowadays, large opencast machines (bucket wheel excavators with up to 10 000 t service weight) are no longer,or only rarely, built. For some years intensive effort has been devoted to the design and construction of alternative machines, and this includes the development of the compact excavator [2] and, in particular, of the Continuous Surface Miner (CSM) [3, 4] (Fig. 1). All the leading machine manufacturers in the mining sector have a share in this development. In view of the increased scope of use of the Continuous Surface Miner (in solid rock) it can be assumed that CSM-technology will in future be of primary importance. Since 1975 Dresden Technical University has been conducting tests on bucket wheel excavators during the digging process (e.g. [5]).

The present studies are adapted to the development trend in mining technology. They are focused on the design and construction of new types of tools for the CSM. Since the mechanized removal of a manageable mass of solid rock always entails a decision involving considerable capital outlay, a reliable prognosis as regards technical equipment is of the utmost importance. Hence, research must also accept these conditions. An adequate basic knowledge and also findings obtained from large-scale tests are essential in order to pursue new methods of design and construction for excavating machines and tools.

2. Bits for CSM Drum Cutters

Nowadays, round-shank bits are used almost exclusively in powerful drum cutters. They were first developed about 30 years ago for use in heading machines. Their efficiency limits have meanwhile been established [6]. They are based on the output capacity of cutting forces as well as on the operating costs as a result of wear on the bits and are expressed as a rock compressive strength of 80 - 100 MPa, a rock tensile strength of 7 - 10 MPa and a wear coefficient of 0.5 - 0.7 N/mm [5, 7]. In order to widen this scope of use roller-bits (disk) were devel-

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1. Einleitung

Gewinnungsverfahren mit direktem Werkzeugeingriff besitzen energetische, ökologische und wirtschaftliche Vorteile [1]. Gigantische Tagebaugeräte (Schaufelradbagger bis 10000 t Dienstmasse) werden heute nicht oder nur noch selten gebaut. Seit einigen Jahren wird intensiv an gerätetechnischen Alternativen gearbeitet, wozu die Entwicklung des Kompaktbaggers [2] aber vor allem die des Continuous Surface Miner (CSM) [3, 4] gehört (Abb. 1). An dieser Entwicklung beteiligen sich alle namhaften Gerätehersteller im Mining-Bereich. Es wird eingeschätzt, daß unter Beachtung erweiterter Einsatzgrenzen (Festgestein) der CSM-Technologie die Zukunft gehört.

Seit 1975 führt die Technischen Universität Dresden Untersuchungen zum Grabprozeß an Schaufelradbaggern durch [5]. Auch heute werden Forschungsarbeiten zur Gewinnungstechnik in großzügiger Weise von der Firma MAN TAKRAF Fördertechnik finanziell unterstützt. Die gegenwärtigen Arbeiten sind dem Entwicklungstrend in der Gewinnungstechnologie angepaßt. Sie widmen sich schwerpunktmäßig dem Gestaltungsprozeß neuartiger Werkzeuge für CSM. Da der maschinelle Abbau eines ladefähigen Haufwerks aus Festgestein immer einer kapitalintensiven Entscheidung bedarf, spielt die sichere gerätetechnische Prognose eine sehr große Rolle. Diesen Bedingungen muß sich auch die Forschung unterwerfen. Ausreichend Grundlagenwissen aber auch experimentelle Erkenntnisse aus Großversuchen sind nötig, um neue Wege bei der Gestaltung von Gewinnungsmaschinen und - werkzeugen zu gehen.

2. Meißel für CSM-Fräswalzen

In leistungsfähigen Fräswalzen werden heute fast ausschließlich Rundschaftmeißel eingesetzt. Ihre Entwicklung hat vor etwa 30 Jahren für den Einsatz in Streckenvortriebsmaschinen begonnen. Heute sind ihre Leistungsgrenzen hinreichend bekannt [6]. Sie ergeben sich aus der Ertragbarkeit von Schneidkräften sowie der Betriebskosten infolge Meißelverschleiß und werden mit einer Gesteinsdruckfestigkeit von 80 bis 100 MPa, einer -zugfestigkeit von 7 bis 10 MPa sowie einem Verschleißkoeffizienten von 0,5 bis 0,7 N/mm angegeben [6, 7]. Um diese Einsatzgrenzen zu erweitern, wurden in den letzten Jahren Rollenmeißel (Disk) entwickelt und mit Erfolg im Berg- und Tunnelbau [8, 9, 10] eingesetzt (Abb. 2). Im Hartgestein besitzt der Disk eine Penetration (Zustellweg) von 5 bis 10 mm, bei mittlerem Schnittlinienabstand t = 40 bis 75 mm. Bei Streckenvortriebsmaschinen ist der Disk ständig im Eingriff. Im Walzenschrämlader (Steinkohle) und im CSM wird der Schnittkontakt während einer Fräswalzenumdrehung unterbrochen (Abb. 3). Hier be-

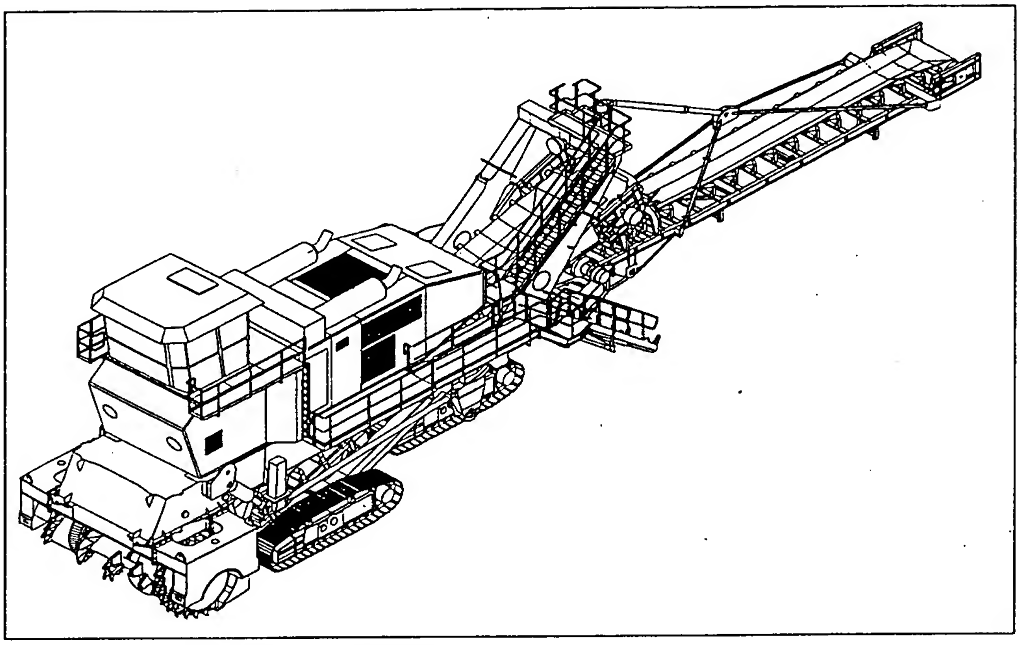
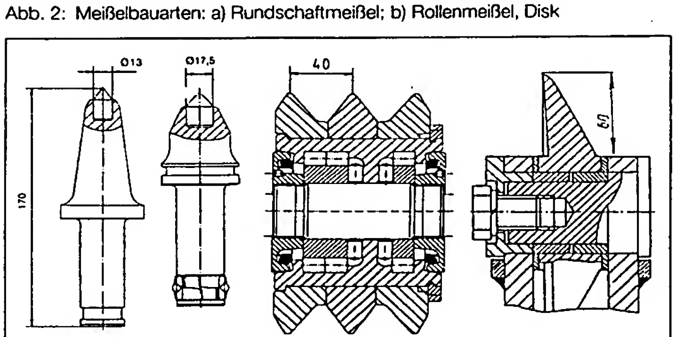


Fig. 1: Surface Miner, type MTS 1250, MAN TAKRAF Fördertechnik GmbH
Abb. 1: Surface Miner, Typ MTS 1250, MAN TAKRAF Fördertechnik GmbH

oped in recent years and used successfully in mining and in tunnel construction [8, 9, 10] (Fig. 2).In hard rock the disk bit has a penetration (delivery path) of 5 - 10 mm, when the mean cutting line spacing t = 40 to 75 mm. In the case of heading machines the disk bit is constantly in contact with the rock. In the drum cutter loader (hard coal) and in the CSM the cutting contact is interrupted during a drum cutter rotation, see Fig. 3. Here the penetration is 40 - 50 mm and the cutting line spacing t ≤ 100 mm. In contrast to the round-shank bit, the rolling action of the wedge-shaped tool (disk bit) produces a "crushing" and, at the same time, a "splitting-off" winning process in the solid rock. Since only a limited motional slip occurs during the rolling action, the specific wear on the bit, as compared to the round-shank bit, is reduced by several orders of magnitude [8]. In order to produce "crushing" and, at the same time, "splitting-off" processes, however, the pressure (Fig. 4) on the disk bit must be very much greater. This interrelationship is taken into account when designing the machine. In the case of heading machines the possible method of anchoring the machine to the surrounding rock is therefore adopted. This is not possible, however, with a CSM.

From observation of the destructive process in the zone of contact between the disk bit and the solid rock it has been ascertained that after penetration a cross-section of ground rock ("crushing" process) is formed first of all as a result of elastic-plastic rock deformation. The pulverized material causes an al-

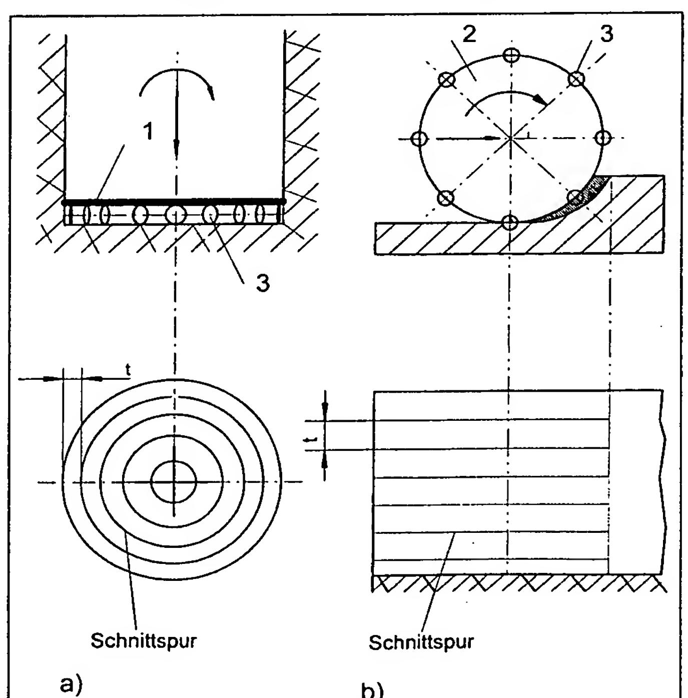
Fig. 2: Types of bits: a) round-shank bit; b) roller bit, disk bit
Abb. 2: Meißelbauarten: a) Rundschaftmeißel; b) Rollenmeißel, Disk



trägt die Penetration 40 bis 50 mm und der Schnittlinienabstand t < 100 mm.

Das Abrollen des Keilwerkzeugs (Disk) ruft im Gegensatz zum Rundschaftmeißel eine "zerdrückende" und zugleich "abspaltende" Gewinnung im Festgestein hervor. Da es bei der Rollbewegung nur bedingt zu einem Bewegungsschlupf kommt, reduziert sich der spezifische Meißelverschleiß im Vergleich zum

Fig. 3: Cutting action: a) uninterrupted disk bit action as exemplified by heading machine, b) interrupted disk bit action as exemplified by CSM. 1) working blade of heading machine, 2) drum cutter, 3) disk bit
Abb. 3: Schneideingriff: a) nicht unterbrochener Diskeingriff am Beispiel der Vortriebsmaschine, b) unterbrochener Diskeingriff am Beispiel des CSM; 1) Arbeitsschild der Vortriebsmaschine; 2) Fräswalze; 3) Disk



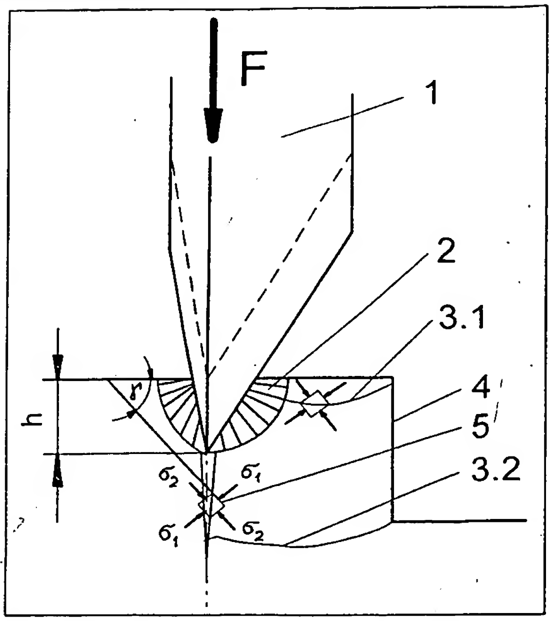


Fig. 4: Effective technique in contact zone between disk bit and solid rock: 1) disk bit, 2) pulverized contact zone, 3.1) macrocrack lines (chips), 3.2) macrocrack lines (slice fragments), 4) open surface, 5) main stresses on cracking element

Abb. 4: Wirkmechanismen in der Kontaktzone zwischen Disk und Festgestein: 1) Disk; 2) pulverisierte Kontaktzone; 3.1) Makrorißlinien (Chips); 3.2) Makrorißlinien (Spanbrocken); 4) Freifläche; 5) Hauptspannungen am Rißelement

most even pressure distribution (quasi-hydrostatic) in the split and subsequently produces a splitting-off effect from the vertically applied bit pressure (Fig. 4). Tensile and shear stresses play a part in the destruction of the rock. The crack formation (crack direction) that precedes the splitting-off process constitutes an innovative starting-point for more effective winning methods.

In the mining sector it is not merely a question of improving the scope of use of the disk bit (in harder rock). High effective output (t/h), lumpiness, power requirement and dust suppression are factors of equal importance. Taking granite winning as an example, splitting-off lengths (chips, see Fig. 4) of only about 10 mm are reached with the present methods, with a penetration of 7 mm and an applied pressure at the disk bit of about 200 kN. Such properties are inadequate for mining tasks.

3. Cutting Process

An analysis of the winning process using a disk bit has shown that there is a very definite relationship between the applied pressure, cutting condition and crack formation. The term cutting condition is used in the sense of the reciprocal effect of cutting processes that take place side-by-side. The disk bits arranged on a drum cutter with varying cutting line spacing then also cause a widely differing splitting-off behaviour. If the crack propagation encounters a free cutting surface, the term free cut is used, otherwise blocked cut (Fig. 4). The limit values of the cutting parameters for a free cut, also referred to as back cut, are generally known. A sure free cut is executed in solid rock when the cutting ratio $v = t/h$ of the cutting line spacing t and the penetration h is 1 to 2. Where the cutting parameters are $v \geq 3$ blocked cutting occurs and partly blocked conditions can be expected between cuts [11].

For the purpose of an analytical description of the cracking processes a wedge-shaped model is used in the elastic-plastic half-space according to the modified *Griffith* theory [12]. The

Runschaftmeißel um Größenordnungen [8]. Um "zerdrückende" und zugleich "abspaltende" Wirkmechanismen entstehen zu lassen, muß aber die Andruckkraft F (Abb. 4) am Disk sehr viel größer sein. Dieser Zusammenhang wirkt sich auf das Maschinenkonzept aus. Bei Vortriebsmaschinen wird deshalb die Möglichkeit genutzt, daß Gerät am Streckenmantel abzuspannen. Bei einem CSM ist das nicht möglich.

Aus der Beobachtung des Zerstörungsvorgangs in der Kontaktzone zwischen Disk und Festgestein ist bekannt, daß sich nach der Penetration infolge elastischplastischer Gesteinsverformung zuerst ein Querschnitt mit zermahlenem Gestein ausbildet ("zerdrückend"). Das pulverisierte Material ruft im Spalt eine nahezu gleichmäßige Druckverteilung (quasi hydrostatisch) hervor und erzeugt nachfolgend aus der vertikalen Meißelandruckkraft eine abspaltende Wirkung (Abb. 4). An der Gesteinszerstörung sind Zug- und Schubbeanspruchungen beteiligt. Die der Abspaltung vorausgehende Rißbildung (Rißrichtung) stellt den innovativen Ansatz für noch effektivere Gewinnungsvorgänge dar.

Im Miningbereich geht es nicht nur um die Verbesserung der Einsatzgrenzen für Disk (festeres Gestein). Von gleicher Bedeutung sind hohe Gewinnungsleistungen (t/h), Grobstückigkeit, Energieaufwand und Vermeidung von Staub. Am Beispiel der Gewinnung von Granit erreicht man mit heutigen Verfahren nur Abspaltlängen (Chips, s. Abb. 4) von etwa 10 mm, bei einer Penetration von 7 mm und einer Andruckkraft am Disk von etwa 200 kN. Für Gewinnungsaufgaben sind solche Eigenschaften unzureichend.

3. Schnittprozeß

Die Analyse des Gewinnungsvorgangs mit Disk hat ergeben, daß es einen sehr deutlichen Zusammenhang zwischen Andruckkraft, Schnittbedingung und Rißbildung gibt. Unter Schnittbedingung ist die gegenseitige Beeinflussung nebeneinander ablaufender Schnittvorgänge zu verstehen. Die in unterschiedlichen Schnittlinienabständen auf einer Fräswalze angeordneten Disken rufen dann auch ein sehr unterschiedliches Abspaltverhalten hervor. Wenn die Rißausbreitung eine freie Spanfläche vorfindet, wird die Bezeichnung Freischnitt, ansonsten blockierter Schnitt benutzt (Abb. 4). Die Grenzen der Schnittparameter für Freischnitt, auch als Hinterschnitt bezeichnet, sind weitestgehend bekannt. Ein sicherer Freischnitt entsteht im Festgestein bei einem Schneidverhältnis aus Schnittlinienabstand t und Penetration h von $v = t/h = 1$ bis 2. Bei Schnittparametern von $v \geq 3$ tritt blockierter Schnitt auf und dazwischen muß mit teilblockierten Zuständen gerechnet werden [11].

Zur analytischen Beschreibung der Rißvorgänge wird das Keilmodell im elastisch plastischen Halbraum nach der modifizierten Theorie von Griffith [12] benutzt. Den Richtungswinkel eines einsetzenden Primärrisses berechnet man danach wie folgt:

$$\Psi_{1,2} = \gamma \pm \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (1)$$

Es bezeichnen:

γ Winkel zwischen der zu schneidenden Gesteinsfläche und der Hauptspannungsrichtung am Element eines Rißereignisses (Abb. 4)

ϕ Winkel der inneren Reibung (Materialkonstante).

Von den nach Gl. (1) möglichen Lösungen bringt immer nur eine Rißrichtung den Makroriß hervor. Die Entscheidung wird vom Spannungszustand in der Rißentstehungszone aber auch von Gesteinsinhomogenitäten getroffen. Die Lösung Ψ_1 beschreibt den Rißrichtungswinkel bisheriger Gewinnungsverfahren mit Disk (Hinterschneiden):

angle of direction of an incipient primary crack is then calculated as follows:

$$\Psi_{1,2} = \gamma \pm \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (1)$$

where

γ is the angle between the rock surface to be cut and the main stress direction on the element of a cracking process (Fig. 4)

ϕ angle of internal friction (material constant)

Of the possible solutions according to Eq. (1), only one crack direction in every case produces the macrocrack. The state of stress in the crack formation zone and also the inhomogeneity of the rock are the decisive factors in this respect. The solution Ψ_1 describes the angle of direction of the crack in winning methods applied hitherto with the disk bit (back cutting)

$$\Psi_1 = \gamma + \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (2)$$

On this basis the following findings were obtained from theoretical and experimental investigations [9]:

- specific power requirement in hard coal 0.2 - 1.0 kWh/m³ (optimized 0.2 - 0.5 kWh/m³)
- specific power requirement in coal interbeds 0.8 - 6.0 kWh/m³ (optimized 1.2 - 2.7 kWh/m³)

In actual mining operations it could be ascertained that the specific power requirement may be considerably lower. In interbeds values in the range of 0.45 - 0.75 kWh/m³ and 0.3 - 1.0 kWh/m³ were determined for aleurolith and argillaceous sandstone respectively [13]. In this connection the cutting parameters t = 70 - 85 mm and h = 35 mm only correspond to the conditions of a free cut in a borderline case. These phenomena cannot be expressed by Eq. (2). The question obtrudes itself as to which hitherto unrecognized cracking process takes place.

An investigation of the state of stress in the contact zone [14, 15] has revealed that during the first rolling action over this zone main stresses in the same direction in the form of $\sigma_1 < 0$ and $\sigma_2 < 0$ (compressive stresses) occur (Fig. 4).

This results in a crack propagation that is directed towards the depth of the rock and not towards its open surface. With each further rolling action a macrocrack increases in size (up to 0.5 m). It is only when main stresses in the form of $\sigma_1 > 0$ and $\sigma_2 < 0$ (tensile, compressive and shear stresses) and not proceeding in the same direction develop in the crack zone that the deeper macrocrack finally also reaches the open surface and thus causes slice fragments. Since this process is connected with repeated rolling action over the same cutting track, the term repeatedly blocked cutting is used. On Griffith's wedge-shaped model this phenomenon can be expressed by the second solution hitherto not applied:

$$\Psi_2 = \gamma - \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (3)$$

From the tests it could also be ascertained that the effect of repeatedly blocked cutting occurs in particular when the pressure of the disk bit is interrupted (Fig. 3). It is assumed that this is caused by the alternate sequence of pressure application and pressure reduction in the surrounding area of the crack.

Theoretically the crack length is unlimited. In actual practice, however, the crack encounters various inhomogeneous features. These also determine the size of the split-off slice fragments. Given the conditions of repeatedly block cutting, the slice dimensions are several times larger than in the case of the free cut. No suitable power requirement model could so far be

$$\Psi_1 = \gamma + \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (2)$$

Aus rechnerischen und experimentellen Untersuchungen entstanden auf dieser Basis folgende Erkenntnisse [9]:

- spezifischer Energieaufwand in Steinkohle 0,2 bis 1,0 kWh/m³ (optimiert 0,2 bis 0,5 kWh/m³)
- spezifischer Energieaufwand in Kohlezwischenschichten 0,8 bis 6,0 kWh/m³ (optimiert 1,2 bis 2,7 kWh/m³).

In der Bergbaupraxis konnte nachgewiesen werden, daß der spezifische Energieaufwand um einen beachtlichen Anteil niedriger liegen kann. In Zwischenschichten wurden Werte für Aleurolith im Bereich von 0,45 bis 0,75 kWh/m³ und im Tonsandstein von 0,3 bis 1,0 kWh/m³ bestimmt [13]. Die Schnittparameter mit t = 70 bis 85 mm und h = 35 mm entsprechen dabei nur im Grenzfall den Bedingungen des Freischnitts. Diese Erscheinungen können mit Gl. (2) nicht erklärt werden. Es stellt sich die Frage, welcher bisher nicht erkannte Rißvorgang zur Wirkung gelangt.

Die Untersuchung des Spannungszustands in der Kontaktzone hat ergeben [14, 15], daß sich bei einer ersten Überrollung gleichgerichtete Hauptspannungen der Form $\sigma_1 < 0$ und $\sigma_2 < 0$ (Druckspannungen) ausbilden (Abb. 4). Daraus folgt ein Rißfortschritt, der in die Tiefe des Gesteins und nicht zu seiner Freifläche gerichtet ist. Mit jeder weiteren Überrollung kommt es zum Anwachsen eines Makrorisses (bis 0,5 m). Erst wenn sich in der Rißzone nicht gleichgerichtete Hauptspannungen der Form $\sigma_1 > 0$, $\sigma_2 < 0$ (Zug-, Druck und Scherspannungen) ausbilden, gelangt auch der tiefergehende Makroriß schließlich zur Freifläche und ruft Spanbrocken hervor. Da dieser Vorgang mit wiederholtem Abrollen in der gleichen Schnittspur verbunden ist, wird die Bezeichnung wiederholt blockiertes Schneiden eingeführt. Am Keilmodell von Griffith läßt sich diese Erscheinung mit der bisher nicht benutzten zweiten Lösung

$$\Psi_2 = \gamma - \left(\frac{\pi}{4} - \frac{\Phi}{2}\right) \qquad (3)$$

erklären. Den Untersuchungen konnte auch entnommen werden, daß der Effekt des wiederholt blockierten Schneidens besonders bei unterbrochenem Diskeingriff (Abb. 3) auftritt. Es wird vermutet, daß die wechselseitige Abfolge von Be- und Entlastung in der Rißumgebung dafür die Ursache bildet.

Theoretisch ist die Rißlänge unbegrenzt. In der Praxis begegnen dem Riß Inhomogenitäten. Sie bestimmen die Abmessungen der abgespaltenen Spanbrocken mit. Unter den Bedingungen des wiederholt blockierten Schneidens sind die Spanabmessungen um ein mehrfaches größer als beim Freischnitt. Bisher konnte noch kein geeignetes Energiemodell unter Bezug auf das Spanvolumen aufgestellt werden. Aus Messungen ist aber bekannt, daß sich ein spezifischer Energieaufwand von etwa 0,3 kWh/m³ für Gabbro, Quarzit und ähnliche Gesteinsarten ergibt. Dieser Energiewert ist sehr viel geringer, als unter den Bedingungen des Freischnitts [14].

Unter Beachtung der beschriebenen Vorgänge eines wiederholt blockierten Schnittvorgangs muß dabei mit einer deutlich spürbaren Bruchkinematik gerechnet werden. Das plötzliche Ablösen größerer Spanbrocken nach einer unbestimmten Anzahl von Überrollungen kann dynamische Wechselwirkungen hervorbringen. Die bisherigen Erkenntnisse haben hierzu gezeigt, daß wegen der hohen Andruckkräfte und ausgleichenden Wirkung einer mit vielen Disken bestückten Walze keine dynamischen Störungen entstehen [16]. Der Zustand des wiederholt blockierten Schneidens kann quantitativ auch mit dem bekannten Schneidverhältnis $v = t/h$ bewertet werden. Als sicherer Wert gilt $v = 4$ für Steinkohle, deren Zwischenschichten und Beton mittlerer Festigkeit [17]. Erste Anzeichen des wiederholt

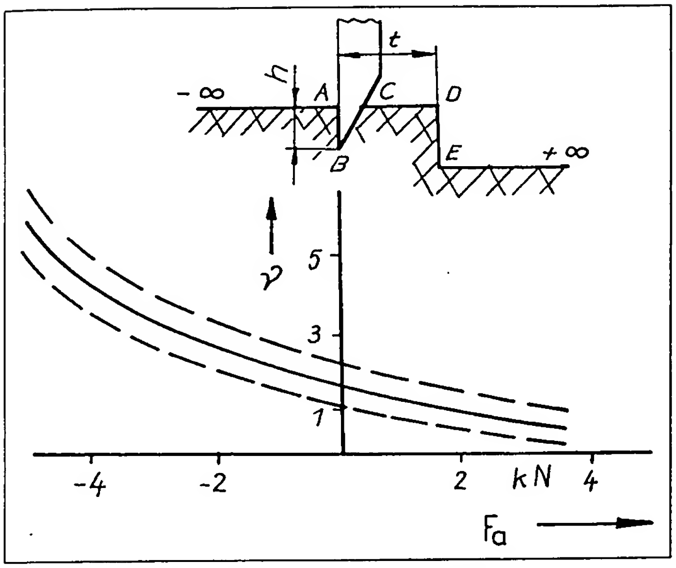


Fig. 5: Effect of cutting conditions of axial force on disk bit
Abb. 5: Einfluß des Schneidverhältnisses auf die Axialkraft am Disk

set up with reference to the slice volume. It has been established by measurements, however, that the specific power requirement for gabbro, quartzite and similar types of rock is about 0.3 kWh/m³. This power requirement is very much less than in the case of the free cut [14].

Taking into consideration the described stages of a repeatedly blocked cutting process, clearly noticeable fracture kinematics must also be expected. The sudden detachment of larger slice fragments after an indefinite number of rolling actions may cause reciprocal dynamic effects. In this connection the findings obtained so far have shown that no dynamic disturbances occur because of the high applied compressive forces and the equalizing effect of a drum cutter euipped with numerous disk bits [16].

The state of repeatedly blocked cutting can be assessed quantitatively also by the known cutting ratio v = t/h. A reliable value for hard coal, its interbeds and concrete of medium hardness is v = 4 [17]. First indications of repeatedly blocked cutting occurred already at v = 2.3. It could be established that the axial force F_a on the asymmetrical disk bit depends in particular on the cutting ratio v (Fig. 5). Given the conditions of a free cut (v ≤ 2.3), the cutting split in the wedge-shaped zone BC does not build up any resistance. During every rolling action a splitting-off process takes place in the direction of the open surface DE. The surface AB of the roller bit is braced against the inner side of the split in such a way that the direction of the forces is changed. These conditions are also evident from the force measurements on the disk bit, as shown in Fig. 6. Whilst a compressive force F_n and a rolling force F_t are formed during the first rolling action as a result of penetration h, the splitting-off process that fails to occur causes a definite resistance in the form of a negative axial force. It is not until the fifth rolling action that a splitting-off process (slice fragments) takes place in the operating zone L and thus also a definite change in direction of the axial force. By reason of the penetration stages (delivery path control) from the first to the fifth rolling process, the applied prsssure and the rolling force have also increased.

The asymmetrical shape of the disk bit has certainly proved effective. Tests to determine the effect of the ratios of the blade angle and the applicability of the measured cutting ratios to other types of rock have still to be undertaken. It can be assumed that the cutting conditions (blocking or splitting-off) are definitely indicated by the axial force. Its direction and magni-

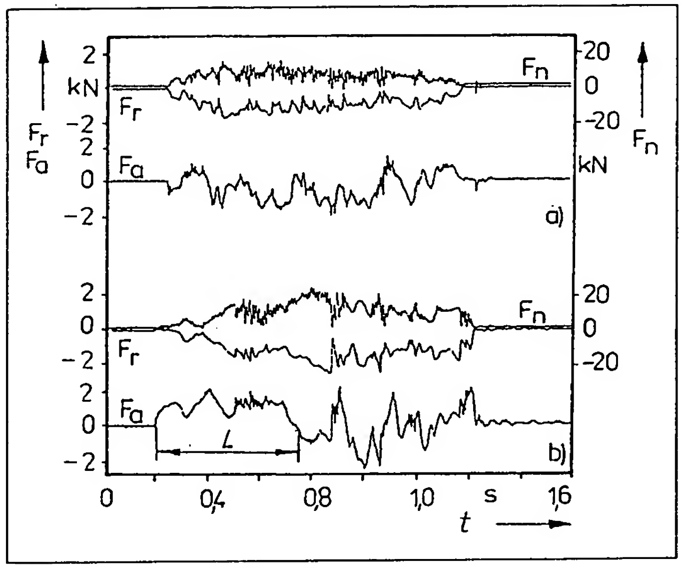


Fig. 6: Forces on disk bit for cutting ratio v = 4: a) measured during first rolling action; b) measured during fifth rolling action
Abb. 6: Kräfte am Disk bei einem Schneidverhältnis v = 4: a) gemessen während der ersten Überrollung; b) gemessen während der fünften Überrollung

blockierten Schneidens traten schon bei v = 2,3 auf. Es konnte nachgewiesen werden, daß die Axialkraft F_a am asymmetrischen Disk besonders vom Schneidverhältnis v abhängt (Abb. 5). Unter den Bedingungen eines Freischnitts (v < 2,3) baut der Schnittspalt im Keilbereich BC keinen Widerstand auf. Bei jeder Überrollung kommt es zum Abspalten in Richtung der Freifläche DE. Der Rollmeißel stützt sich mit seiner Fläche AB im Spalt derart ab, daß es zu einer Kraftrichtungsumkehr kommt. Diese Verhältnisse werden auch aus den in Abb. 6 dargestellten Kraftmessungen am Disk verdeutlicht. Während sich bei der ersten Überrollung infolge Pentration h eine Anduckkraft F_n und Rollkraft F_t ausbildet, ruft der ausbleibende Abspaltvorgang einen deutlichen Widerstand in Form einer negativen Axialkraft hervor. Erst während der fünften Überrollung kommt es im Arbeitsbereich L zum Abspalten (Spanbrocken) und damit zu einer deutlichen Richtungsumkehr der Axialkraft. Aufgrund der Penetrationsschritte (Wegsteuerung) vom ersten zum fünften Überrollvorgang sind auch Anduck- und Rollkraft angestiegen.

Die asymmetrische Form des Disk hat sich grundsätzlich bewährt. Untersuchungen zum Einfluß der Keilwinkelverhältnisse und zur Übertragbarkeit der gemessenen Schneidverhältnisse auf andere Gesteinsarten stehen noch aus. Es kann davon ausgegangen werden, daß von der Axialkraft die Schnittverhältnisse (blockiert oder abspaltend) eindeutig angezeigt werden. Ihre Richtung und Größenordnung ist aber auch für stabile Schneidverhältnisse an einer Fräswalze verantwortlich.

4. Zusammenfassung

Gewinnungsverfahren mit direktem Werkzeugeingriff verfügen über viele Vorteile. Ihre Anwendungsgrenzen sind bezogen auf Gesteinsfestigkeit, Verschleißteilkosten, Grobstückigkeit und Staubentwicklung vom Rundschaftmeißel und Disk (Freischnitt) bekannt. Erst durch bewußtes Einstellen von Schneidverhältnissen beim Arbeiten mit Disk, lassen sich diese Anwendungsgrenzen deutlich erweitern. Es kommt zu einem Gewinnungsvorgang, der als wiederholt blockiertes Schneiden bezeichnet wird. Die Untersuchung der Lösemechanismen erklärt die bisher als Phänomen erkannten Vorgänge. Sie ermöglichen nunmehr das Bemessen geeigneter Werkzeuge und Gewinnungsmaschinen (CSM). Zur Umsetzung der Schneidverhältnisse sind weitere Forschungsarbeiten nötig.

tude are, however, also responsible for stable cutting conditions on a drum cutter.

4. Summary

Mining methods with the cutting tool in direct contact with the rock have numerous advantages. Their limited scope of applicability in relation to rock hardness, costs for wearing parts, lumpiness of material and dust emission when using round-shank and disk bits (free cut) is known. It is only by effective adjustment of cutting conditions when using a disk bit that this limited applicability can definitely be improved.

This results in a winning process that is referred to as repeatedly blocked cutting. An investigation of the stripping techniques explains the processes hitherto known as phenomena. These now make correct dimensioning of suitable tools and excavating machines (CSM) possible. Further research is however necessary as regards the practical application of the cutting conditions.

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